
Irrigation and Drainage Systems **14:** 41–67, 2000.

Diagnostic analysis of the Maricopa-Stanfield Irrigation and Drainage District area *

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Accepted 18 November 1999

Abstract. Diagnostic Analysis (DA) is a methodology for assessing and understanding the performance of an agricultural system. This analysis is the first step in a large system change process, known as the Management Improvement Program (MIP), whose objective is to improve the performance of the agricultural system. A group of Federal and state of Arizona agencies agreed to apply the MIP methodology in a western U.S. setting. The purpose of the application was to test the applicability of the MIP approach and to refine the methodology. This paper describes how the DA methodology was applied in the Maricopa-Stanfield Irrigation and Drainage District (MSIDD) area in central Arizona, USA, and summarizes the lessons derived from that experience. Specific findings of the DA study and the response of MSIDD area agriculture to those findings are discussed in separate articles.

Key words: performance, systems analysis, action research, diagnostic analysis, collaborative approach, interdisciplinary, integrated resource management, irrigation management, irrigation performance, managed change, strategic change, strategic management, sustainable agriculture, systems change, water conservation

Introduction

In this century, irrigated agricultural development has helped to stabilize and increase food production in many regions of the world. For many countries, the additional agricultural production made possible by irrigation is also an important source of foreign revenue. While irrigated agriculture continues to provide significant benefits to society, it also has created problems. Irrigation development has occurred at the expense of water-dependent natural environments. Further, water management practices in many agricultural regions

have contributed to long-term degradation of water quality in both surface and groundwater and to soil salinization. In many hydrologic basins, development of additional renewable water resources is economically, politically, and/or socially infeasible, and a few basins face potential crisis conditions caused by over-allocation of the available water resource.

While it is widely recognized that water management has to be improved to assure the sustainability of irrigated agriculture, agreement on how to achieve this objective is more difficult because of the complexity of the production system. Crop production and economic returns depend on the availability of various resources besides water. Throughout the growing season, the farmer has to decide when and how to use these resources to meet his production objectives. These resource allocation decisions, including irrigation practices, must satisfy constraints imposed by crop biological and weather factors, factors internal to the farm (e.g., technology, labor, financing) and factors external to the farm (e.g., water delivery rules, local regulations, crop prices, environmental regulation, market preferences). Many factors influencing water management decisions are unpredictable. Weather is highly uncertain in the short-term, but water supplies, crop prices, and energy costs may be highly unpredictable in the medium- and long-term. Adding to this complexity is that the irrigated agricultural system includes more than one farmer or farm unit. These individual agricultural enterprises compete against each other for common resources and markets, yet many strongly depend on each other for their well-being. This is the case, for example, of farmers who depend for their water supplies on a user-maintained and financed water delivery system, where the economic failure of one individual negatively affects the capacity of all users to financially maintain the system. Also, irrigation practices impact the quantity and quality of the water supplies for alternative water users within the same hydrologic basin such that changes that may be beneficial to one particular group of farmers may be detrimental to other farmers or other water users. Clearly, then, a regional perspective is a requirement for improving agricultural water management. Furthermore, a systematic understanding of the performance of the entire system and the reasons for the observed levels of performance are a prerequisite to any successful change effort.

Diagnostic Analysis (DA) is a methodology for assessing and understanding the performance of agricultural systems. The DA is the first step in a process, based on organizational development, known as the Management Improvement Program (MIP). The objective of the MIP is to improve the performance of the agricultural irrigation system in a region (Figure 1). The DA methodology has been under development since the 1980's, initially under the sponsorship of the USAID-funded Water Management Synthesis II

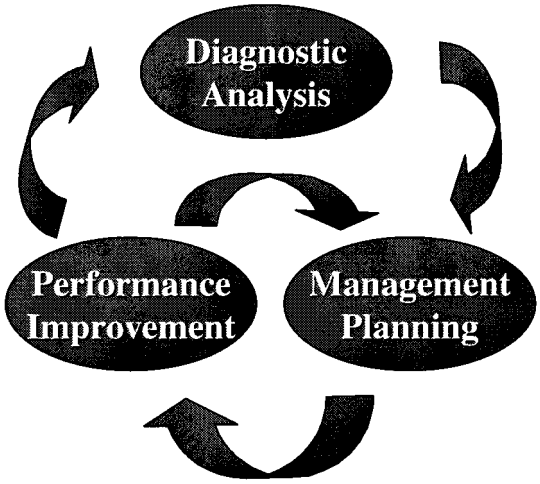

Figure 1. The three phases of the Management Improvement Program. Diagnostic analysis yields an interdisciplinary understanding of the performance of irrigated agriculture in the area. Management Planning results in a shared understanding of the performance among stakeholders, joint identification of opportunities for improvement, and planned managerial and technological changes to address those opportunities. Performance Improvement results in implementation of the plans and establishment of long-term, self-supporting mechanisms to sustain high performance.

Project (Jones & Clyma 1988). The results of the DA are used in the structured MIP process as a basis for irrigation system stakeholders to identify priorities for improving the system's performance, developing collaborative action plans aimed at addressing those priorities, and establishing the foundation for coordinated implementation of programs (Jones & Clyma 1988). The diagnostic analysis and management planning elements of this MIP approach have been applied to irrigation projects in Asian and African countries (Clyma & Lowdermilk 1988).

A group of Federal and state of Arizona agencies, known as the Interagency Management Improvement Program Coordinating Group (IMIP CG),[1] agreed to apply the MIP methodology in a western U.S. setting. The purpose was to test the applicability of the MIP approach and to refine the methodology. Dedrick et al. (2000) provide background information and a chronology of the MIP demonstration project, which was conducted in the service area of the Maricopa-Stanfield Irrigation and Drainage District in central Arizona, USA. An initial step in the MIP demonstration was the development of a Diagnostic Analysis study of the MSIDD irrigated agricultural system. This paper describes how the DA methodology was applied and summarizes learnings from that experience. Detailed DA findings are too extensive to be presented herein; therefore, those findings and the response of

MSIDD-area agriculture to those findings are discussed in separate articles (Bautista et al. 2000a & b; Clemmens et al. 2000; Wilson & Gibson 2000).

DA methodological background

Various methodologies for studying the performance of irrigation systems have been proposed. These methodologies vary widely in perspective and data requirements. Some methodologies are engineering-research oriented and look exclusively at measures of water resource utilization (Clemmens and Bos 1990, Bos et al. 1994, Keller et al. 1998). Others focus more strongly on measures of economic performance and/or social impact and are of greater interest to policy makers (Molden et al. 1998; Bandaragoda 1998). Methodologies have also been developed for use by irrigation system managers to determine alternatives for positive change. Diagnostic Analysis falls within this last category. More specifically, the main objective of Diagnostic Analysis is to understand the performance of agricultural systems in total, as opposed to studying specific but narrower quantitative aspects.

The Diagnostic Analysis methodology evolved over several years as part of irrigation research and development in developing countries (Fowler 1983; Lowdermilk et al. 1983; Clyma & Lowdermilk 1988). The Diagnostic Analysis framework originates from various concepts. One of these concepts is systems analysis, which is widely used to study complex systems, including physical, biological, and human systems. Its purpose is to characterize the environment in which a particular activity occurs, to understand how the various system components interact with each other, and to understand how these components influence the activity being investigated. The irrigation system is the environment within which the irrigation activity occurs.

Small and Svendsen (1990) provide a particularly useful definition of an irrigated agricultural system. The irrigation activity centers on the farm and, therefore, the farm unit is the initial level of the irrigation activity environment. Another level of this environment is the community of water users in the region who are physically linked through the water delivery system or through the underlying groundwater basin. Economic factors represent still a different level of the environment; and they include financial institutions, suppliers of productive inputs, markets, etc. There are also social and political components in the environment, including local institutions and traditions, and state or national support and regulatory policies impinging on the irrigation/agricultural activity.

Another element of the Diagnostic Analysis framework is the use of interdisciplinary teams. In this sense, Diagnostic Analysis researchers make a strong distinction between multidisciplinary, intradisciplinary, and inter-

disciplinary studies (Lowdermilk et al. 1983). In the former, specialists in a particular discipline would examine a system component from their individual perspective. The final study would then be a compendium of these separate perspectives. The intradisciplinary study attempts to integrate this knowledge, but typically one or a few individuals combine the assessment's developed by individual specialists. In an interdisciplinary study, specialists share the data and interpret the findings through a consensus-driven process. Thus, the final interpretation is one that fully captures the views of all team members.

A key concept in the Diagnostic Analysis framework is Action Research (French and Bell 1990, Cunningham 1993, Nadler 1977, Whyte 1991). The purpose of Action Research is to develop data and knowledge that can be used to advance organizational change. Thus, in Action Research, researchers and study subjects share the data, interact with each other to reach a new understanding of findings, and initiate change actions. Action Research has been used for a variety of purposes, including advancing agricultural technology development and diffusion, defining alternative organizational work structures in industrial settings, and influencing individual behavior. Data are collected in action research programs to explain why individuals undertake particular activities and how these activities are influenced by their context. Hence, the data generally are qualitative, thus, requiring careful interpretation by the researchers. Rapid appraisal techniques are commonly used to obtain these kinds of data.

There are many similarities between Diagnostic Analysis and the Farming Systems Research and Development approach (Shaner et al. 1982). They share the concepts of systems analysis, interdisciplinary studies, and Action Research.

Diagnostic Analysis is a flexibly structured process. An important characteristic of the process is its management. Clyma and Lowdermilk (1988) define five distinct stages for the study. In the first, an overall start-up plan is developed. Participating entities, including study subjects, become formally involved in the process during the second stage. An initial exploration occurs during the third stage, the results of which are used to identify and prioritize research areas. The fourth stage is the actual field study. During the last stage, findings are summarized and reported, and researchers and study participants share the findings with the wider community and begin laying foundations for subsequent improvement efforts. This stage also marks the beginning of the second phase of the overall MIP effort, the Management Planning Phase (see Dedrick et al.2000, for a description of the MIP phases). These activities are carried out with the support of a trained facilitator and specific team management tools (i.e., the Team Planning Methodology, Levine 1989).

These management tools are used, for example, to outline the process to be followed, monitor its progress, resolve conflicts, train the study teams, and to assure that the perspectives of the various interdisciplinary team members are integrated.

An overview of the MSIDD Diagnostic Analysis activities

DA planning and preparation

The Maricopa-Stanfield Management Improvement Program was initiated in December 1990 through an agreement between the MSIDD board of directors and the MIP sponsors, the Interagency Management Improvement Program Coordinating Group (IMIP CG) (Dedrick et al. 2000). A MIP Management Team[2] was formed to specify and guide the process. MIP planning began in early 1991, with initial attention focusing on the DA Phase.

The MIP Management Team developed an overall strategy to carry out DA planning activities. These activities began at a preliminary meeting in March 1991 with the participation of MSIDD and IMIP CG representatives. The meeting was devoted primarily to identifying agricultural and water management issues of concern to the various entities in the area. Although the formation of a local oversight team was envisioned at this time, the idea did not materialize until later, during the Planning Phase, and in a more broadly constituted interorganizational form than originally conceived.

Meeting participants developed the initial research objectives and defined the MSIDD-area agriculture subsystem on which DA research would focus: namely, on-farm water control, delivery system water control, economics, farm agronomic productivity, and social-organizational aspects. Participants also agreed on a broad structure to carry out the process, which would involve two different teams, one to carry out the field study (the DA Team[3]), and another to provide additional technical expertise and feedback (the DA Resource Team[4]). The MIP Management Team was responsible for managing the DA process and also functioned as part of the DA Team. Human resources that would need to be recruited for these tasks were also identified.

Planning continued during a five-day DA start-up workshop in April 1991. In addition to individuals involved in the initial planning, other participants included potential DA team members, representatives from support and regulatory organizations carrying out programs in the MSIDD area, sociological and agricultural economics consultants, and other individuals with knowledge of the MSIDD area or the DA process. Objectives of the workshop were to develop among participants a shared understanding of the DA phase of the MIP and of the study's research areas, to define the DA teams, to agree on a

framework to guide the process, and to concur on roles and responsibilities of the various teams and team members.

DA Teams

The DA Team, along with the four MIP Management Team members, was directly responsible for implementing the DA and reporting the DA findings. DA Team members were recruited for their specific disciplinary expertise, expertise with the DA process, or their knowledge of the area's farmers and agricultural situation. Because the DA approach is based on achieving a team-wide understanding and synthesis of system performance, certain personal characteristics were also required of DA Team members. Each was expected to provide disciplinary input strongly and forthrightly in terms understandable to team members from other disciplines and to avoid disciplinary bias and defensiveness that could obstruct shared understandings or team syntheses.

Members of the larger DA Resource Team were selected because of their knowledge and experience in technical aspects of the agricultural system or in the DA process. They assisted the DA Team in preparation for its work and later provided critical review of the evolving DA findings and process. The Resource Team included members of MSIDD management, members of the IMIP CG, and other technical experts.

DA data sources

The DA Team's data collection strategy was based primarily on in-depth study of the farm enterprises within the MSIDD service area and of the MSIDD itself. These data were collected through structured interviews of farmers and MSIDD employees. Organizations other than MSIDD, though involved in irrigated agriculture in the area, were not studied directly. Information pertaining to these organizations was obtained indirectly from the farmers or MSIDD and assessed in terms of the knowledge and experience of DA Core and Resource Team members, usually including one or more members of these organizations.

Background information was also studied for relevant data. These sources included journal articles and design reports about MSIDD's irrigation system, articles and reports about irrigated agriculture in the area, organizational information about current programs and practices, water delivery records, and economic data that included farm budgets and annual financial reports from other irrigation districts in the West.

Development of sub-system research objectives, preliminary exploration, and development of data collection instruments

The DA Team outlined the data collection process and developed the necessary instruments in June 1991. Data acquisition focused first on identifying a set of applicable objectives for each of the key MSIDD-area agricultural subsystems – farm, water delivery, economics, and social-organizational. Then, team members developed hypotheses relative to the perceived current performance and factors that might be causing such performance. A set of questions was developed that could be addressed in a two-hour interview. Data acquisition instruments (questionnaires) were then tested with a small number of farmers. These initial interviews provided the DA Team with experience in the use of the questionnaires and enabled refinement of the research hypotheses and interview questions. Separate questionnaires were developed later for farmers, foremen, and irrigators; for MSIDD operators, management, and administrative staff; and for the members of MSIDD's board of directors (BOD) (some of whom also were interviewed as farmers). Each questionnaire included questions specific to the role of the individual being interviewed along with others that were asked of all interviewees.

Many questions were open-ended and formulated to elicit a process description without leading the interviewee to an anticipated response, e.g., a question might solicit a description of the interviewee's role in a process and the criteria used to make decisions while carrying it out. An example of such a question is, "How do you determine when to change irrigation sets?" Other questions were formulated for more specific responses (e.g., numerical values, or yes/no responses). Key to the interviewing process was its focus on understanding specific processes hypothesized to have a significant impact on system performance.

Study population and farmer sample

District management first sent a letter to potential interviewees informing them of the board's decision to participate in the MIP. In a follow-up letter, the DA Team Leader notified the subjects who had been selected for interviews, provided those individuals additional information on the purpose of the MIP application, and reassured them that the data obtained would be confidential. Forty-seven cotton farmers were identified as the population from which a sample of 27 farmers was selected using the criteria described below. Twenty-five of the 27 farmers were interviewed. Thirty of the 45 MSIDD staff, ranging from a sampling of canal operators to all of upper management were interviewed, as were all 9 MSIDD board members.

Various factors were considered when defining the farmer sample. Given that 85% of the area's farmed acreage was planted in cotton, with the remainder in alfalfa, citrus, grains, grapes, pecans, and vegetables, selection was limited to farming parcels where cotton was the primary crop. Further, since surface irrigation is used exclusively for cotton in the area, sampling was limited to surface irrigated parcels. Land tenure status (owned versus leased land) was not considered in determining the sample. It was hypothesized that larger acreage would be more difficult to manage, and thus, might be less efficient. Thus, the acres managed were subdivided into three groups; $<$300 ha, 300-600 ha, and $>$600 ha. Farmers in the $<$300 ha category tended to receive water from 1 or 2 farm turnouts, with the 300-600 ha and $>$600 ha categories having 2 or 3 and $\geq$ 4 turnouts, respectively. Another factor was location along the lateral canal. This was defined by the number of active farm turnouts in the lateral between the farmer in question and the main canal. Here the categories were $<$ 2, 2 to 5, and $>$ 5 turnouts. With two factors and three levels for each factor, there were nine combinations in the sample. Turnouts, coded to the various farmer's properties, were randomly selected until four farmers were chosen for each combination. The fourth farmer in each category was an alternate. Once a farmer was selected, that farmer's remaining turnouts were removed from the sample so that he could not be chosen again. Data collection focused on the acres served by the turnout in question and not the farmer's entire acreage.

Background material

Background material germane to the study area was collected and interim analysis began shortly after the April workshop. Printed materials were identified by various DA Team members and were gathered in a central repository, which also served as headquarters for the DA Team. These materials were reviewed by the DA Team member with the appropriate disciplinary expertise, and relevant content was then summarized and shared with the entire DA Team. This process of materials gathering and review continued throughout the DA.

Field interviews

All interviewing was done by two-person subteams. Four subteams were formed for this purpose; two interviewed farmers, foremen, and irrigators; a third team interviewed MSIDD personnel; and a fourth the BOD members. In general, the subteams changed neither their subject focus nor their membership. These teams established common interview procedures. During an interview, one subteam member led the conversation while the second mem-

ber asked appropriate follow-up questions and helped maintain the interview flow. Roles were often rotated, and subteams' debriefings included attention to the interview process as well as its content. During the interviews, both members of the subteam recorded responses and explanatory notes.

Each interview began with the interviewee being briefed about the MSIDD-Area MIP and the purpose and future use of the interview. Confidentiality as to the source of the information provided was assured, and the importance of interviewee insights, openness, and cooperation were emphasized. At the end of each interview, interviewees were informed of the subsequent steps of the DA and thanked for their participation.

Interview data were coded and entered into a spreadsheet format. In many instances, statistical analyses of these data helped provide an understanding of system performance. For anonymity, questionnaires from all interviews were filed according to farmer or MSIDD employee number, and summary data forms were filed with each questionnaire. Field data collection began in mid-June and was completed by mid-August. Because of other demands on team members' time, data collection was intermittent during this period.

Interim analysis, summary, and synthesis

The foundation for the final data synthesis was provided by the subsystem definitions and hypotheses developed during the early planning stages. The DA processes (Clyma & Lowdermilk 1988) were supported and guided by the Team Planning Methodology (TPM, Levine 1989) as the DA Team gathered and synthesized a large amount of data and shaped it to provide an accurate, comprehensive, and consistent picture. As a starting point, the DA Team restated their original hypotheses to be statements of subsystem performance. In the process of summarizing and synthesizing their understanding, team members replaced the hypotheses with *Performance Statements* that describe conditions associated with irrigated agriculture in the MSIDD area, framed from the DA Team's current understanding. For each Performance Statement, the team wrote an *Impact Statement*, specifying how that performance would affect the profitability and sustainability of the system, and a set of *Contributing Factors*, identifying the primary causes of the level of performance including a limited amount of explanatory information or supporting data. The specification of contributing factors (i.e., causes for high or low performance) is a key feature of the DA approach. This identification of causes links directly to identifying important opportunities for performance improvement in the study area. Only Performance Statements considered by the DA Team to have significant performance impact were included in the final DA findings. Prioritization of Performance Statements and associated issues were addressed during the Management Planning Phase.

The DA Team's interim analysis, summary, and synthesis processes were critical parts of their DA work. In essence, the final DA synthesis was simply the last iteration of an activity that began when the first data were collected. The process can be described as re-telling the story of what is going on with irrigated agriculture in the area. The story, however, must accommodate all the data as well as the various disciplinary interpretations of the individual DA Team members. When elements are contradictory or suggest incompatibility, further data gathering and reinterpretation are required; when new data either suggest missing chapters of the story or undercut current aspects, more work and discussion of what has been learned are required. Each reiteration of the story represents a consensus among DA Team members, not just agreement of a majority. Members were urged to apply their disciplinary perspectives rigorously, to clarify for each other any technical matters that might block full understanding, and to verify any data that seemingly could not be accommodated. Iterative and interdisciplinary development of the "story of irrigated agriculture in the MSIDD" led directly to the acceptance of the DA results. Because of the rigorous interdisciplinary analysis, farmers, MSIDD employees, including the Board of Directors, and other agency personnel were convinced that the data analysis and conclusions described in the performance statements were complete and correct.

Early iterations of Performance Statements were challenged and changed, usually because they oversimplified or overstated a condition, ignored important district history or impacts from the broader context, had a more negative tone than proved accurate in terms of the larger picture, or omitted or left as implicit statements of performance strengths. An example of the evolution of process used and the resulting an economic subsystem Performance Statement follows:

For each of the subsystems (farm, water delivery, economics, and social-organizational), several objectives were formulated. Boundaries were defined for each. From these definitions, performance measures and initial areas of inquiry were identified. These various definitions for the economic subsystem are summarized in Table 1.

DA Team members then identified subobjectives for the system and developed Performance Statements related to these subobjectives. Using the available data, they then identified various factors contributing to or explaining the stated performance. Table 2 presents examples of early versions of the economic subsystem objectives and related performance statements. These were developed from the initial hypotheses after some field data had been collected. Next, for each performance statement, a list of contributing factors was developed. Examples of early versions of contributing factors associated with the first of the Performance Statements of Table 2 are listed in Table 3.

Table 1. Economic subsystem definitions.

Objective	Maximizing the welfare of families served by MSIDD
Boundaries	– farm
	– MSIDD, input suppliers, commodity buyers, support and regulatory organizations
Performance Measures	– water use/cropped acre – 1989, 1990, 1991
	– cropping pattern
	– net farm income
	– yields per acre
	– yields per unit volume of water
	– total acres land farmable
Inquiry Areas	– farm size
	– total acres farmed
	– legal organization of farm
	– irrigation system technology
	– relationships with organizations

Final versions of these statements are presented in Table 4, and are discussed in the following section of this report. Notice that these final statements are broader than their initial versions.

It should be noted that while the Performance Statements in Table 2 and contributing factors in Table 3 were meant to describe the economic subsystem, some statements have implications for the performance of other agricultural subsystems (e.g., farm, water delivery, social/organizational). Performance Statements and contributing factors were added, deleted, or modified as more data were collected.

Final synthesis, formulation of the DA findings, and development of the DA report

In August, the DA Team concurred on a set of findings and produced a draft report in September. The initial draft was reviewed in a series of DA Team meetings, resulting in a new, more coherent, and defensible iteration of the findings than the initial draft. This draft was then used in a series of reviews with the DA Resource Team, the MSIDD BOD (two reviews), MSIDD Management (three reviews), the area's farmers, and the IMIP CG. These groups were each asked to provide input in terms of the accuracy and clarity of the DA findings and the contextual information provided, and more generally, for fine tuning the draft. At each of these reviews, the DA Team found both

Table 2. Example of early formulations of Objectives and Performance Statements for the economic subsystem.

Objectives	Performance Statement
1. Returns on investments to farmers are sufficient to sustain irrigated agriculture.	1. The cost of MSIDD water makes long-term farming in the area uneconomical.
2. Farmers adopt state-of-the-art irrigation technology to provide the highest levels of efficiency, yields and net returns for farmers in the district.	2. The high costs of improved irrigation technologies have limited their adoption
3. Improved practices are adopted by farmers to reduce farm production costs and maximize net returns.	3. Farm profitability has declined due to increasing costs of production.
4. Proper soil tilth should be maintained through crop rotations to ensure improved crop production and better water management.	4. The cost and availability of water has forced farmers to adopt practices that are degrading to the soil.
5. MSIDD farmers have an interest in and means to adopt appropriate new technologies to sustain and increase profitability.	5. Adoption of new technologies is inadequate to sustain and improve profitability.
6. Irrigated farms in the MSIDD need to be profitable while remaining of a size that can be efficiently managed.	6. Diversified operations in terms of number of farm units, legal structure and farm size, manage their water suboptimally.
7. Government regulatory programs should not inhibit farm productivity by reducing the time the farmer can spend on managing the irrigated farm.	7. Government regulations increase the cost (implicit) of running a farm.

a higher-than-expected level of interest and a general concurrence in the importance, relevance, and comprehensiveness of the performance assessment. Issues that arose were discussed, and as in the earlier synthesis processes, increased understanding brought increased concurrence. The involvement and contributions of the review groups, in particular of MSIDD's BOD and Management, while conflictive at times, provided ongoing serious and significant improvement in the DA performance assessment. The review process lasted, with some interruptions, from September 1991 through February 1992, with a final report completed in March 1992.

Throughout these reviews, though most of the Performance Statements were reworded or modified in some way, content was not compromised. That

Table 3. Example of initial contributing factors for economic subsystem Performance Statement 1 (Table 2).

1.	Less than timely delivery of water produces crop stress and reduces yields and therefore incomes for farmers.
2.	Less than timely and dependable delivery of water increases labor costs for farmers.
3.	The high per acre assessment charge increases fixed costs and reduces flexibility of farm decisions.
4.	High operation and maintenance (O&M) costs for the district increase the costs of water to farmers.
5.	Inadequate communication between operator, foreman, ditchrider and MSIDD management decreases farmer flexibility and increases costs.
6.	Reduced margins of profitability and uncertainty of cotton prices, and insects, weather, government policy and financing conditions make management decisions for profitability more difficult.

is, the DA Team did not modify its conclusions for political reasons or to avoid controversy. In general, it was able to address satisfactorily issues raised by all parties, including MSIDD management and farmers. The widespread concurrence in the DA findings is important confirmation of the ability of the process to yield its intended product. This acceptance continued throughout the MIP, with the findings being used and built upon as plans were developed.

DA findings

As the DA findings continued to evolve, it became increasingly difficult for the DA Team to synthesize its results strictly according to the original subsystem definitions. Ultimately, the DA findings were organized into the three broad performance areas given in Tables 4-6, namely

- Economic viability of the area's irrigated agriculture;
- Management of farm units, the district, and its interfaces; and
- Technology adoption and upgrading.

Only final objectives and performance statements are listed in the tables. The list of contributing factors and a detailed explanation of each factor can be found in Dedrick et al. (1992a). Bautista et al. (2000a), Clemmens et al. (2000), Bautista et al. (2000b), and Wilson and Gibson (2000) detail some of these results as they related to the on-farm, water delivery, and economic subsystems. Tables 4-6 also show that Performance Statements developed initially to address a particular objective eventually were found to apply to

Table 4. Final Objectives and Performance Statements for Performance Area 1: Economic viability of the MSIDD irrigated agricultural system.

Objectives		Performance Statement	
1.	Returns to farming are sufficient to sustain well-managed irrigated agriculture in the district.	1.	The current level of water costs and assessments, combined with yield and price variability, creates uncertainty in net returns for farm operations.
2.	The input supply system (e.g., credit, fertilizer marketing services, etc.) contributes to the farmer's ability to be profitable.	2.	Constraints and conditions on the supply of credit reduce farmer flexibility in production and marketing decisions.
3.	MSIDD delivers water to individual farmers in a cost-effective and efficient manner.	3a.	Farmed acreage in the district is declining.
		3b.	MSIDD is managing its relatively high debt position through efforts aimed primarily at debt restructuring.
		3c.	MSIDD Management is using groundwater to stabilize water costs to the farmer.
		3d.	MSIDD's variable non-water costs[a] represent a significant percentage of the net unit cost of water to the farmer.
4.	Agency support programs serve to increase farm sustainability and MSIDD viability.	4.	Although external agency programs produce benefits to the farmer, some significantly increase reporting, compliance, and information-gathering costs (measured in time, effort, fees, etc.) to both the farmer and MSIDD.

[a] "Variable nonwater costs" include payroll and benefits, repairs, supplies, services and professional fees, and other charges. See Dedrick et al. (1992b) for the specific data that were provided by MSIDD.

more than one objective and that more than one Performance Statement was needed for some objectives.

The DA report delves heavily into economic issues. This depth is a reflection not of biases within the DA Team but of the overwhelming reaction of local farmers. When the field interviews were conducted, farmers were already experiencing the effect of the Central Arizona Project (CAP) eco-

nomic and financial crisis. Wilson and Gibson (2000) discuss the economy of MSIDD agriculture in 1991, and Wilson (1992) discusses the bigger picture of CAP agriculture during the early 1990s. It was not surprising, then, that farmers were interested in talking about economic issues. MSIDD personnel and board members had similar concerns, and many of those conversations also focused on economic subjects. Although there was considerable emphasis on economic issues during the interviews, the information collected delineated a wide range of performance in soil and water management practices among MSIDD farmers and it was these that eventually became the focus of the MIP later in the program. These findings are discussed in greater detail in Clemmens et al. (2000).

MSIDD personnel interviews yielded a detailed picture of water delivery practices and of the interface between the district and the farmers. This comprehensiveness is explained by two factors. First, interviews were conducted with most of the district's employees representing all its organizational levels. Second, district management engaged fully in the DA Report review process – learning, correcting, and translating their new understandings into action while they insisted on correcting inaccuracies, they also took seriously the identification of problem areas in MSIDD's organization and operation.

Agency data were collected only from the farmers' perspective. Therefore, although the impact of support and regulatory agencies is examined in the report, these findings are not as extensive as those related to farm economics, management, and district operations. These findings were ultimately used, becoming the starting point for subsequent internal assessments and program and procedure modifications by the participating agencies.

The DA report revealed and clarified the difficult economic situation confronted by the MSIDD agricultural system. The report identified a set of circumstances, some external to MSIDD but many internal, that were contributing to the observed levels of system performance. Also, a strong economic interdependency among farmers and between farmers and district, not previously understood by farmers and district personnel, was identified.

Ultimately, the DA results effectively highlighted a wide range of opportunities for improving management at the farm level, in the water delivery service, in the delivery of programs by support agencies; and in addressing economic issues associated with water supply agreements between and among the water purveyors of Central Arizona Project water and MSIDD.

Table 5. Final objectives and Performance Statements for Performance Area 2: Management of the farm units, the District, and its interfaces.

Objectives	Performance Statement	Applies to Obj.
1. Farmers take appropriate management actions to improve productivity and return on investment while maintaining acceptable levels of sustainability.	1. Water use for a given crop (e. g., cotton) varies widely within the district, depending on soils, irrigation systems, and management practices; this implies there are opportunities for improvement.	1, 2
2. Farmers assure that water is applied to fields efficiently, in a timely manner, and in amounts, flows, and uniformity appropriate to the irrigation system used, and to improved productivity and profitability.	2. Because of the standard water delivery service window (on and off), the flexibility and timing of water delivery service vary within the district; this influences farm irrigation operations, management practices, and investment in technologies.	3, 4
3. MSIDD's delivery of water supports effective farm enterprise management across differences in farm size, soils, crops, irrigation systems, and location within canal systems.	3. Soil-building conservation measures such as the use of small grains, alfalfa, cover crops, manure, and reduced tillage systems are inadequately employed to sustain the farming system.	1
4. System design, technologies, and operational procedures for both off- and on-farm water control support optimal system performance.	4. The quantity, quality, and dependability of water delivery has generated a positive production environment for water users in the district; however, current overall system performance may be lower than system potential, and some delivery procedures difficult to sustain.	4, 5, 6, 7
5. MSIDD obtains and manages an overall water supply that is adequate to meet crop water requirements, groundwater use goals, and overdraft regulations.	5. While the farmers and the MSIDD Board, management, and employees are quick to praise their working relationships and communication, there are specific areas where these processes could be strengthened.	6
6. Shared goals, positive working relationships, and effective communication systems and patterns exist among all organizations and farmers involved in irrigated agriculture within the district and contributed to economic sustainability.	6. The ability of MSIDD operating staff to deliver the requested flow rate and maintain it over time without significant fluctuation varies within the district.	3

Table 5. Continued.

Objectives	Performance Statement	Applies to Obj.
7. MSIDD Management plans, operates, and monitors its performance for continuous improvement, including the achievement of high staff performance levels.	7. Some MSIDD operational rules that might improve delivery service to many farmers are neither widely known nor used; some farmers are uncertain about other rules that appear to have been developed for particular situations.	5, 6, 7

Accomplishments, lessons learned, and recommendations for future DA applications

The positive assessment of the DA at its conclusion in early 1992 was confirmed in an evaluation study conducted in late 1993 to evaluate the overall MIP effort and to develop recommendations for improving the process (LeClere et al. 1994).[5] The study was based on interviews of MSIDD-area farmers and members from the MSIDD and various other organizations that participated in the program. Members of the DA Team also were interviewed. This section summarizes the findings relative to the DA and provides recommendations for improving the DA process. The recommendations presented herein expand on those originally presented by LeClere et al. (1994).

The Diagnostic Analysis study met its goals of yielding a comprehensive description of the MSIDD-area irrigated agricultural system. This was the unanimous opinion of those directly involved in the DA planning, execution, and final report review as well as of respondents who were involved in planning phase activities and who, therefore, actively used the DA findings for program development. The study's interdisciplinary perspective was often cited as one of its most valuable attributes. Equally valuable was the focus on particular MSIDD agricultural subsystems, namely MSIDD economics, farm management, and water delivery operations. To some interviewees, the learning generated by the DA was the most significant contribution of the MIP. The interdisciplinary nature of the DA findings and their relevance to the ultimate purpose of promoting change in the agricultural system needs to be emphasized. The findings of the MSIDD- area DA underline the interrelatedness of the performance impact of the various components of the agricultural system. They provide useful and accurate information because they address multiple system components and reflect the interdisciplinary

Table 6. Final objectives and Performance Statements for Performance Area 3: Technology adoption and upgrading.

Objectives	Performance statement	Applies to Obj.
1. Farmers and MSIDD Management each explore technological alternatives, collaboratively where appropriate, and adopt those that provide improved levels of efficiency, profitability, and sustainability.	1. Farmers' adoption of new or improved irrigation technologies has been limited, and in some cases, incomplete.	1, 2
2. New or improved technologies continue to deliver their intended performance over time.	2. Agency technology transfer efforts have had only limited success in effecting the rate of technology upgrading or new technology adoption by farmers.	2, 4
3. Water delivery and application procedures and performance support the adoption of new and improved on-farm technologies.	3. Though MSIDD's ultrasonic flow meters are effective for water accounting and billing purposes and for operational management if properly used, they are rarely used by farmers as management tools, and in general it appears they could be more effectively used by MSIDD personnel.	1, 2
4. Agencies supporting the use of new or improved on-farm and/or MSIDD operations technologies and management collaborate effectively with both farmers and MSIDD in selecting appropriate options and achieving their projected impacts.	4. The intended transfer of remotely monitored and operated control (supervisory control) and its operational management procedures was not accomplished as planned, and as a result, the interim manual control procedures were continued, and further developed.	2, 3

nature of the performance in both their statement and their supporting data. While some contributing factors are single-discipline oriented, the set of contributing factors for a given performance statement represents a combination of factors across different disciplinary perspectives. This is as it should be; since actual performance is a result of causes across disciplines and across system components, an accurate and useful performance assessment will be interdisciplinary. Consider the following Performance Statement:

> Though MSIDD's ultrasonic flow meters are effective for water accounting and billing purposes and for operational management if properly used, they are rarely used by farmers as management tools, and in general it appears they could be used more effectively by MSIDD personnel.

Such a statement would not have resulted from analysis by any single discipline expert, yet this statement clearly described the use of these meters by MSIDD-area water providers and users in 1991.

The DA findings proved valuable in initiating change within the MSIDD agricultural system (Bautista et al. 2000a). It is important to note that much of the DA information was obtained through rapid appraisal methods and is based on qualitative data. Nevertheless, because the findings made sense in terms of the experience of area groups and agencies, the process was still able to generate organizational change-despite both the uncertainty and limited amount of detailed quantitative data. The DA had its greatest impact on the irrigation district organization. Such would be expected, since the water delivery service and its impact on farm water management was a key focus of the overall MIP effort and was studied in great detail.

The DA experience proved to have a particularly strong and valuable impact on individuals directly involved in the DA study, e.g., DA Team members. Some of these people reported changing their approach to their jobs and modifying the programs they were involved in because of the improved understanding brought about by the DA. In this regard, one respondent stated that "for everything I learned about the farmers, I learned two things about my own agency." This statement summarizes one of the key characteristics of the DA process: its ability to generate a sense of ownership of the data, a step critical to the acceptance and confidence in the feedback loop of organizational change efforts.

At a broader level, the DA findings contributed to the development of a subsequent study on Central Arizona Project agricultural economics by one of the DA Team members (Wilson 1992) This study, in turn, influenced the development of state of Arizona policies aimed at resolving the Central Arizona Project economic crisis of 1992-94. These issues are discussed in greater detail in Wilson and Gibson (2000).

While the evaluation showed that the DA was directly valuable to organizations involved in the MSIDD-area agriculture, the impact on farmers was less clear. Farmers who participated in the MIP's planning and implementation activities became familiar with those findings, but no evidence was found that the DA Report was widely read or understood by other farmers. However, DA Team members did point out the possibility of suggestive learnings resulting from the DA interviews, during which farmers were forced to reflect on why they were following particular farming practices.

Another important learning from the DA experience was the value of a facilitated structured process when conducting interdisciplinary work. Team members were divided into small groups for various tasks. The DA Team process required confident individuals with solid disciplinary commitment and understanding. Each team member brought different skills and different communication abilities and styles of interaction. Each also differed in the desire and ability to advocate ideas. To prevent strong personalities from dominating, the role of the facilitator was to focus that strength in positive directions for achieving the Team's goals and to encourage less forceful team members to speak up. When one team member disagreed with others, the facilitator sought to assist that member in representing his/her perspective, without defensiveness, until the entire team was in agreement. Another facilitator role was to press for clarity and closure, which sometimes seemed at odds with each other, on identified performance areas or statements. Early on, this pressure created periodic tension and resistance to the process because DA Team members were eager for more data and more analysis of existing data. However, these tensions dissipated as pride in the progress and quality of the work continued to grow.

DA Team resourcing was a significant problem. Participation in the MSIDD MIP was a voluntary effort, and members of the DA Team were recruited from support, research, and educational organizations. Although some individuals contributed their time as part of an agreement made by their agency to participate in the MIP, others were recruited without any formal agreement. In essence, organizations were not reimbursed for the time these individuals spent on the project even though the project was additional to their primary responsibilities. This "borrowing" of resources appeared to have not greatly affected individuals working for larger organizations, which have greater manpower, but it created significant difficulties for individuals working for smaller organizations. Adding to this problem was the time over which the DA study was conducted. Planning, development of interview guides, team preparation, and field interviews took about six working weeks. The field interviews were completed in less than four weeks. Final synthesis and report development, however, took nearly eight months. While the DA Management Team undertook much of the report drafting and review responsibilities, still the DA Team members continued to provide input to the Management Team and responded to new report drafts. This process periodically created additional time demands on DA Team members.

Evaluation study recommendations also addressed the use of Action Research principles. Although, in general, the MSIDD MIP application followed Action Research principles, the DA process departed from conventional action research guidelines in one significant way. Action research calls for early,

systematic review and interpretation of the data by those who were original sources of the data and those who would benefit from its uses. In the MSIDD MIP application, this review process was introduced only after the DA Team had summarized its findings in the form of Performance Statements, which were then used to develop drafts of the report. These drafts were fed back to the DA Resource Team, which included members of MSIDD's management, and to the board of directors for their review and interpretation. The reaction of MSIDD management upon this initial exposure to the findings was negative and threatened the continuation of the MIP. At that point, the DA findings identified a number of relatively low performance situations associated with MSIDD that were initially considered by MSIDD representatives to be external criticism. Once MSIDD management had an opportunity to clarify the findings and the DA Team's understanding that had led to them, the DA report was accepted. Although the ensuing review process strengthened MSIDD's commitment to the program, the transition from the DA to the planning phase was probably slower and more cumbersome than it might have been. LeClere, et al. (1994) observed that the quality of the DA report, its local credibility and acceptance, as well as a willingness to act on it, would benefit from a broad, early feedback and refinement process; and further, that the more these feedback and refinement processes are valued as elements of the transition from the DA to the Management Planning Phase, the more natural these phases would flow together.

This failure to build into the DA earlier use of Action Research review methods may be rooted in the lack of clarity of the role of the DA Resource Team revealed by the evaluation study. This team was meant to serve two roles: a technical role as reviewer of the DA progress, and as its membership included local stakeholders, the role of local oversight. These roles were not clearly differentiated and at times conflicted; thus, the effectiveness of the Resource Team was limited. In this respect, the reader must keep in mind that the overall MIP was a pilot effort conducted to test the process and that the need for a local oversight group (beyond the MIP Team) was not recognized. Such a local oversight group would have established a clear agreement as to how and when the DA data would be fed back to the DA study subjects, an essential aspect of the use of qualitative data in an organizational development process (Nadler 1977). In the case of MSIDD farmers, their early participation in the DA-findings review occurred through members of the board of directors. Other farmers were not involved until later, when the report was nearly finalized. When DA Resource Team members were asked to conduct an initial review of the report draft, they were not conducting a technical review, which was their original role, but rather, they were completing the organizational feedback loop of the process.

The MSIDD DA proved successful as a process to gain an understanding of the performance of an area's irrigated agricultural system and to determine the level of that performance in the MSIDD area. Limiting the DA's focus to the farmers and the irrigation district served both aspects of that purpose. However, it also limited assessment of the impact of relevant support and regulatory agencies. The information that was obtained about other agencies came only from the farmers and MSIDD personnel and during feedback from members of the DA Resource Team. Thus, while the MSIDD DA provided an excellent baseline relative to the management of the district and farm units, it could only partially fill that role for relevant agencies. Nevertheless, while evaluation results indicated that the MIP, and more specifically the DA study, positively impacted agencies' understanding, attitudes, and relations; the lack of initial data makes the change more difficult to assess. Failure to collect data directly from these other stakeholders early in the DA was not an oversight; the MIP Team recognized its desirability but decided that time and resource constraints precluded data collection of that breadth.

The MSIDD experience is that the focus, purposes, and context of the DA and MIP application need to be stated clearly from the beginning, and that planning and execution of the DA Phase must be guided by these initial decisions. The ultimate success of the MSIDD DA was due largely to sponsors and stakeholders having agreed from the outset on the purpose of the application. Although early in the process the district was uncomfortable in the unfamiliar role as study subject, they came to understand that they were only one piece of the MSIDD agricultural system and that looking introspectively at their operations was a necessary aspect of the DA process. Despite the time and resource constraints that precluded in-depth investigation of the roles of other stakeholders in the MSIDD agricultural area, it is clear that ongoing strengthening of the agricultural system requires that all key stakeholders take a similar in-depth look at their own roles and activities and that they develop ownership of the DA findings equally as strongly as that of the district's management.

The above discussion suggests that the DA was, indeed, a valuable learning experience that led to individual and organizational change. These changes appeared strongest in those individuals or organizations most directly involved in the process. If the DA is a form of learning that leads to action, then those responsible for actions need to play significant roles during this learning process. Therefore, in future applications of the DA process, the MIP DA Management Team needs to involve a broader range of local resource people in a variety of roles to help plan and execute the study. In addition to technical and managerial input from agency, academic, and other institutional experts directly involved in the problem arena, the team should

consider careful and purposeful involvement of other local leaders to help facilitate the DA process and interpret the data it yields. Clearly, the need to include appropriate disciplinary expertise and local representation must be balanced with cost and time constraints. Furthermore, identifying the local leaders who should be involved may not necessarily be evident at the beginning of the process. Because of the project's experimental nature, making these determinations was particularly difficult.

Conclusions

The Diagnostic Analysis phase of the MSIDD demonstration MIP proved to be a unique learning experience for those involved in the study as well as for other MSIDD agricultural area stakeholders. The study yielded valuable insights on the performance of the agricultural system, which depart from the type of information that normally would be obtained through engineering or economic studies of the performance of irrigated agricultural systems. The DA identified the critical interrelationships between the irrigation district and other agencies' policies, and many aspects of farm management decisions from water scheduling to soil management. Some of these interrelationships were not predictable. The interdisciplinary nature of the DA study allowed the integration of the knowledge of the technical experts who conducted the study with the knowledge and experience of the study subjects. The end result was a report that was widely accepted by MSIDD area stakeholders informed of the DA results, and in some instances spontaneous change occurred in the agricultural system. As intended, the DA findings provided the foundation for carrying out the planning phase activities of the MIP.

Notes

1. Entities represented were Arizona Departments of Water Resources and Environmental Quality, The University of Arizona Cooperative Extension, USDA-Natural Resource Conservation Service (NRCS, formerly Soil Conservation Service), USDA-ARS-U.S. Water Conservation Laboratory (USWCL), and U.S. Department of Interior-Bureau of Reclamation (USBR). Representatives of two additional agencies, the Arizona Department of Agriculture and The University of Arizona, joined this group later.
2. MIP Management Team membership was constituted to provide leadership over broad areas – conceptual, managerial, relational, and technical – while infusing the overall process with vision. In practice, this charge translated into directly developing and facilitating MIP events, maintaining ongoing communication with participants, addressing specific concerns and problems as they arose, developing and publishing MIP-related documents, and maintaining records and files. Also, as an element of the overall Action Research approach to the IMIP effort, the MIP Management Team held periodic multi-day planning

sessions to assess the MIP's progress, to plan and replan as needed, and to identify interim lessons learned that seemed relevant to the present and future MIP applications. The first five authors of this paper made up the MIP Management Team with Dedrick leading the team and Clyma (MIP specialist) and Levine (management/team planning specialist) serving as consultants to the program.

3. The DA Team included Albert J. Clemmens and John A. Replogle, Water Control: On-Farm and Water Control: Delivery, respectively, USDA-ARS USWCL; Richard D. Gibson, Social-Organizational, The University of Arizona Cooperative Extension, Pinal County; Paul N. Wilson, Economics, Dept. of Agricultural Economics, The University of Arizona; and Ralph E. Ware, Agricultural Productivity, USDA-NRCS, Casa Grande, Arizona, District Office. MIP Management Team members Dedrick, Clyma, Levine, and Rish augmented the DA Team by participating in and assisting with data collection, analysis, and synthesis.
4. The Resource Team was an interorganizational group of supporting and involved organizations that provided guidance and oversight to the DA process. Entities represented were: MSIDD, Arizona Departments of Water Resources and Environmental Quality, USDA-NRCS and USDA-ARS USWCL, USDI-USBR, Irrigation Management Service, and The University of Arizona Cooperative Extension. The Resource Team was augmented by two outside consultants, a sociologist, and an economist.
5. Evaluation team members were William E. LeClere, Organizational Development Specialist, Luray, Virginia; and Bautista and Rish, USDA-ARS USWCL. 1 "Variable nonwater costs" include payroll and benefits, repairs, supplies, services and professional fees, and other charges. See Dedrick et al. (1992b) for the specific data that were provided by MSIDD.

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